Low-Cost Spaceframe Housing Concept

Skip Trantow
skip@omnigarten.org
May 2, 2021

Dear Members of the PDX Shelter Forum:

I would like to propose 'spaceframe' building technology as an additional tool for providing affordable housing for Portland.

Spaceframe theorists and architects like Alexander Graham Bell, Buckminster Fuller, Konrad Wachsmann and Peter Pearce have set the stage for applying spaceframe technology to housing. Whereas they generally focused on large structures, I propose that we can purpose spaceframe concepts to small structures to create tiny-house villages in urban areas where it is unfeasible to build with conventional construction methods.

When viewed through the lens of conventional housing methodology, our urban landscape looks fully developed. However, when viewed abstractly as a three-dimension space, without preconception of what housing should look like, we realize there is a lot of developable open space in, above and around this gridwork of residential and commercial enclosures. Through the lens of spaceframe technology, we can 're-see' the urban landscape and realize that there are many spaces where we can build clusters of durable, aesthetic, deeply affordable, permanent 1 to 2 person living units.

A spaceframe can be generally characterized as a set of tubular steel struts that are bolted at their endpoints to a 'connector joint' to create a three-dimensional geometric network of nodes in patterns of triangles and squares. In geometric terms, a spaceframe is a Tetrahedral-Octahedral Lattice. Bucky Fuller called them 'OctTet Trusses'. Every node in a spaceframe is 'triangulated' giving the overall structure exceptionally high load bearing stability across long spans at lower cost than wood, steel I-beam, or reinforced concrete solutions. From a small, standardized set (kit) of strut and panel types a wide variety of spaceframe shapes and sizes can be built. Spaceframe structures can be 'truss planes' (platforms), 'polyhedral enclosures' (living units) or 'linear tubes' (connectors/walkways).

In this concept proposal I focus solely on platforms, i.e., the 'space-truss'. The idea is inspired in large part by the design of architect Peter Pearce's Ecohouse[1].

Unlike conventional buildings where a load-bearing concrete foundation generally corresponds to the perimeter of the house and requires many interior supports, because of the high spanning and load-bearing capabilities of an Octet space-truss, support-to-ground can be concentrated onto a comparatively small number of augured-and-poured concrete columns. This key characteristic makes it technically and economically feasible to create buildable space for housing in the residential/commercial/industrial urban gridwork that conventional construction methods cannot. The figures below, from Peter's book 'Beyond

---

[1] See: https://www.amazon.com/Beyond-Green-Century-Architecture-Ecohouse/dp/151764027X . Note that Peter's website http://pjpearcedesign.com has architectural detail, but is not working due to use of Flash.

Green' show the salient aspects of his design that, I believe, could be effectively re-purposed to provide building platforms for low-cost tiny house villages.

Figure 1 shows two views of the envisioned Pearce Ecohouse, a case study of a large, single-family residence built on steep terrain in the Santa Monica mountains overlooking Los Angeles that uses space-trussing throughout. This proposal is all about applying this same space-truss design principle to create just platforms, upon which, we can situate multiple tiny houses.

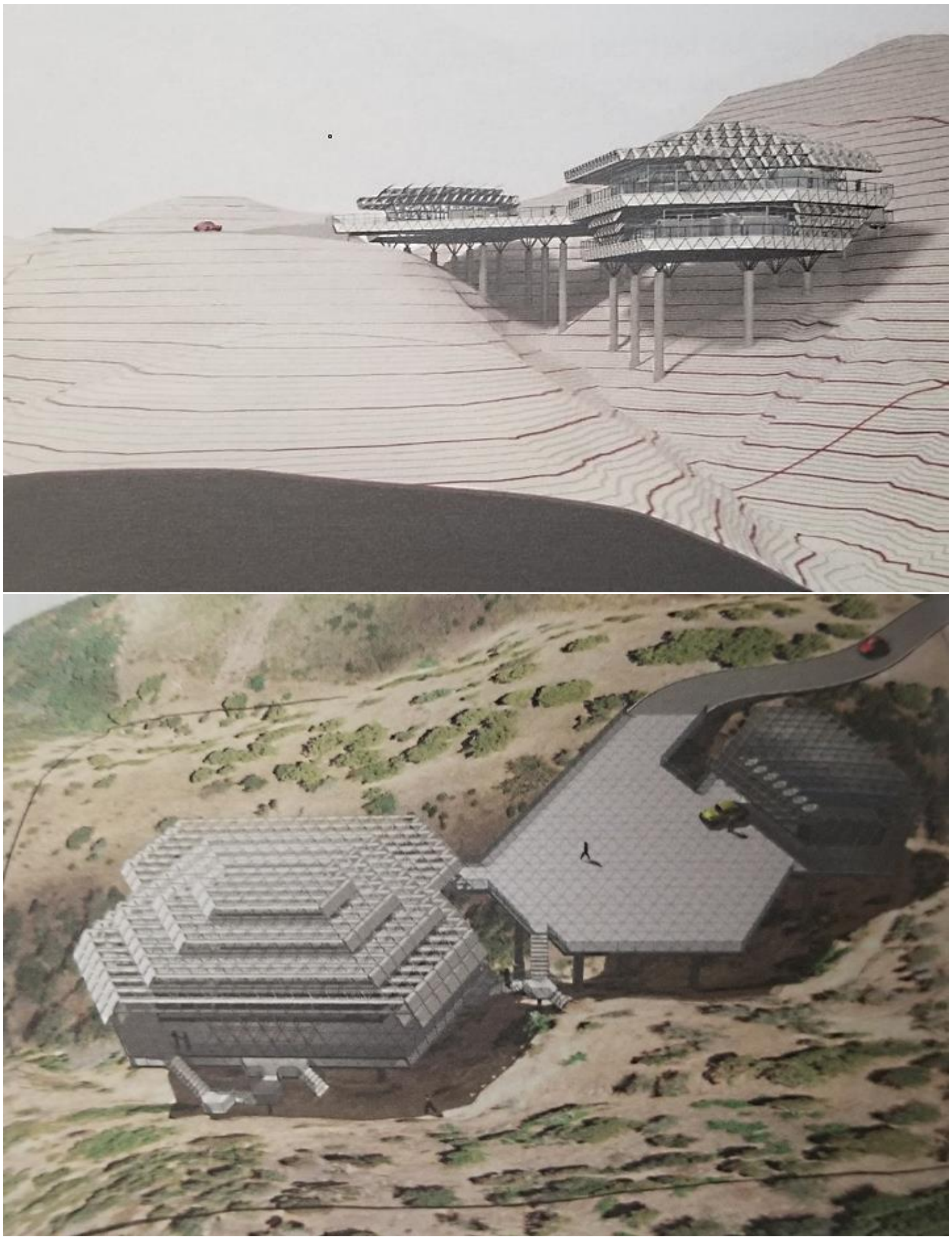

Figure 1: Envisioned Pearce Ecohouse Residence

Figure 2 shows the topology of the building site and the first building stage after holes have be bored and concrete columns poured. It is evident here that, in this topology, it would be unfeasible to build using conventional methods.

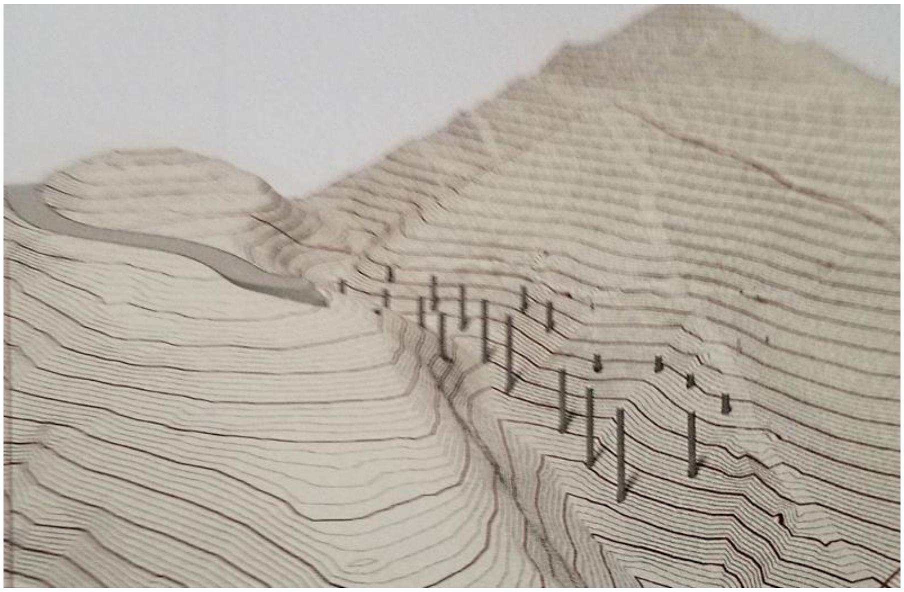

Figure 2: Support columns of poured concrete columns placed on uneven steep topology.

Figure 3 shows the lower-level space-truss platform in place and anchored to the concrete columns.

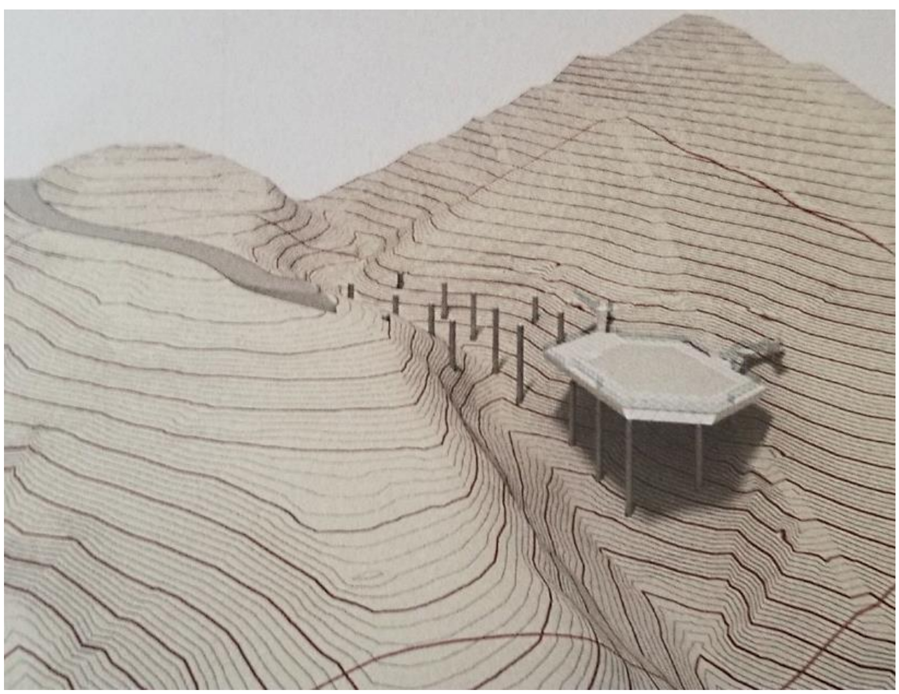

Figure 3: A single space-truss platform in place.

Figure 4 shows that multiple levels of truss platforms are possible. All constructed from the same, standardized kit of parts. Here vertical 'truss walls' support the second platform. Imagine a cluster of tiny homes, and even a large common kitchen and sanitary unit, placed on these platforms.

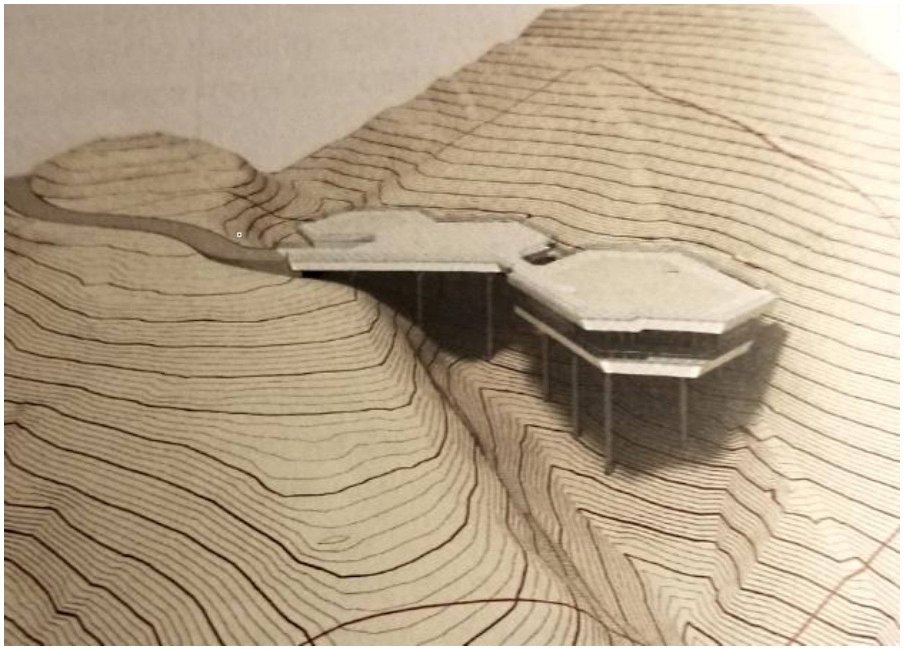

Figure 4: Tiered and inter-connected space-truss platforms in place.

Figure 5 is a cutaway view of the residence that conveys the truss geometry for platforms and walls.

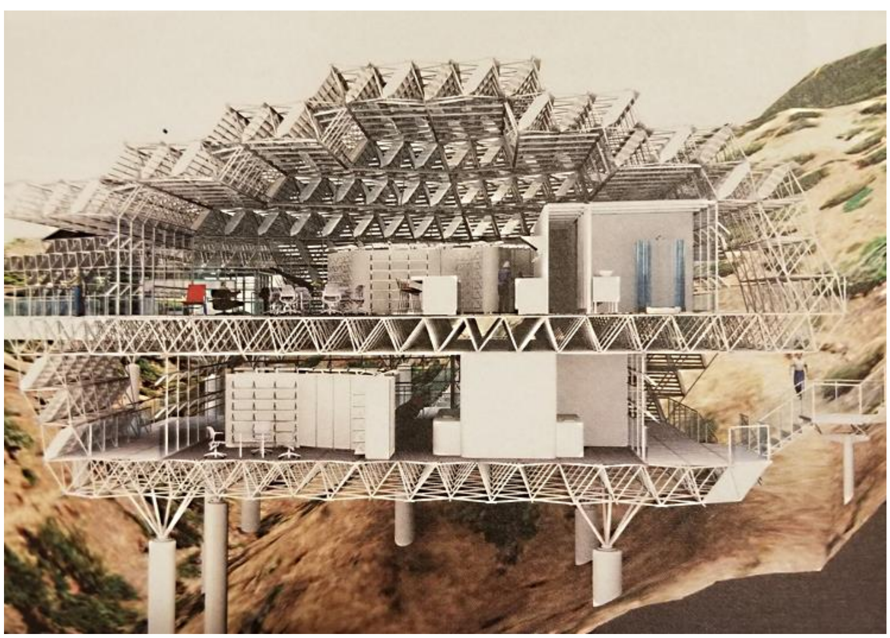

Figure 5: Pearce Ecohouse Cutaway

Notice the long, almost unreal, lateral spans of the lower deck between its support columns, and the use of vertical spaceframe walls to support the upper deck and roof.

Peter Pearce on Design Vocabulary (from Beyond Green Pg31)

"The Pearce Eco-House is a unique architectural solution that is developed around a design vocabulary that is distinct from traditional barn or residential construction. It is a vocabulary that has emerged from both theoretical studies, (see: Structure in Nature is a Strategy for Design, The MIT Press, 1978, 1990, Peter Pearce), and considerable practical experience in the design, engineering, and construction of advanced building systems. These include sophisticated space-trusses (mostly of steel), and innovative glazing and cladding systems. Perhaps the most well known of these projects is the previously mentioned Biosphere 2, in Arizona."

Floor panels for spaceframe platforms would be designed to easily affix to the plane of space-truss struts, creating flat, walkable 'artificial land' on which to place housing units. A floor panel on a space-truss platform is an equilateral triangle, likely with edge lengths of 3ft or so that it can be handled by a single person. Whereas Peter Pearce seals the roof and walls with glass panels and uses concrete/ceramic panels for the open deck (platform) areas, I envision a simple floor panel made of sturdy sheet-metal with an anti-slip, rust-proof coating. The panels would be perforated to allow water to drip through. (If there is more than one level, then the top level may need to have solid and water-tight panels to protect the layer below from rain.) Using metal floor panels would greatly reduce the cost versus glass glazing and concrete panels of the Pearce design. Metal panels can easily be stamped out, coated and affixed.

There are many kinds of housing units we could anchor on a space-truss platform. Polyhedral domes have been dabbled with for some time, however, a prefabricated metal Quonset-style unit (with a door and a window placed in the end panels, with a kitchen counter, a bed platform, a bathroom, and a small sitting area) strikes me as a cost-effective, and aesthetic, choice. The image in Figure 6 is but one example of a Quonset Hut tiny house.

Figure 6: Quonset Hut Tiny House Example

Upon the stable and flat space-truss platform multiple prefabricated tiny housing units, with areas in the range of 100-200ft², could be anchored. For example, on a 1500ft² (50ft x 30ft) platform, four 200 ft² (20ft x 10ft) prefab housing units could be sited with ample access pathways and privacy patios, creating a tiny neighborhood. Depending on the site, multiple such neighborhoods could be interconnected by space-truss walkways.

To get a sense of scale, each level of the two-level residence portion of the Pearce Ecohouse is 2720 ft², the detached garage is 1217 ft², the deck between the residence and garage is 5228 ft². Spaceframes will basically scale linearly in cost to any size and can be formed into any space geometry.

Key Value Proposition:

Spaceframe technology allows us to build on urban spaces that are not economically feasible, or structurally possible, to build on with conventional methods. Such 'unbuildable' land will likely be far less expensive to procure than your typical flat urban lot.

There is a spectrum of 'space harvesting' opportunity, from easy to aggressive, that can potentially yield significant amounts of new buildable space for tiny house villages:

- The easy opportunities are sloped, craggy urban spaces (public or private) where it is cost prohibitive to excavate and construct conventional foundations and buildings.
- Irregularly shaped spaces where an inter-connected series of custom-shaped spaceframe platforms can be laced through. The long spanning capability of spaceframe affords more flexibility to tailor its shape.
- Aggressive harvesting might entail elevated space-truss platforms, 1 to 1.5 stories high, that are built above and across:
  - Alleyways or Driveways. This solution would yield housing space above yet retain low-volume traffic access below.
  - Seasonal washes/swales. Natural area below intermittently space platforms would remain intact.
  - One-story non-residential buildings.
  - Sections of commercial parking lots where the ground level could remain useable for parking.
  - Elevated platforms that run above and along residential property boundary lines to capture backyard open space.

Key Attributes of Spaceframe:

- **Low component cost:**
  - The geometry of spaceframe, i.e., the size and shapes of struts and panels, the design of connector units, has been determined. It is established art. No need to invent novel methods.
  - Construction 'kits', comprised of standard-length struts and uniform connectors and panel types, can be mass-produced locally, using simple, well-known metal fabrication and production techniques, resulting in low overall cost.
  - Components can be factory coated to ensure that finished structures are permanently weather-resilient resulting in low maintenance costs.
- **Low construction cost:**
  - Excavation and foundation work minimized. Environmental impact and remediation cost minimized.
  - The most cost-effective foundations would likely be reinforced concrete columns that are poured into augured holes.
  - Platform sub-sections can be prefabricated in a factory and trucked to the site for assembly thereby speeding up overall assembly of platforms.
  - On-site assembly of individual struts, prefabbed sub-sections, and floor panels is a repetitive and regular process. Simple training requirements for assemblers.
  - Components can be handled by a human worker minimizing the need for heavy lifting equipment, except when prefabricated platforms sections are put in place.

- Conventional mobile cranes and boom buckets, conventional hands tools, etc. can be used in the assembly process.
- With plenty of space under and within the spaceframe platform, hook-up of electrical, data and plumbing utilities is easy.
- Metal Quonset-style housing units are relatively inexpensive and simple to factory build. They can be trucked to site where they are bolted onto the platform. They are weather-resilient and easy to maintain.
- After the foundation columns are set and utilities interfaces are in place, truss components and housing kits are delivered to the site. The work of platform assembly, anchoring the tiny homes to the platform and getting a village into a move-in state is likely in the range of a few weeks.

Intrinsic Value of Geometry:

- Space-truss geometry distributes load stress as evenly and broadly as is possible, resulting in an extremely strong structure that is as light-weight as possible. The 'magic' here is that these opposing parameters - strength and lightness - come in a geometric form that has flat 2D surfaces - the perfect building platform!
- The value of spaceframe is also in uniformity: Uniformity of its component parts, uniformity of the assembly process. A simple, standardized 'kit of parts' yields a fully triangulated truss platform that is extremely strong and stable.
- The stability and load-bearing capability of spaceframe trusses will likely meet city building codes and requirements. High-wind and earth-quake resilience.
- High flexibility to shape the platform to fill a variety of open space geometries.

Peter Pearce on Geometry (from Beyond Green Pg32)

"The building shape is also designed for maximum structural advantage. The shape is guided by the concept of 'strength of geometry'. In this concept, the dominant parameter for structural engineering is building shape, not strength of materials. Although necessary, strength of materials is considered a second order engineering parameter. In this design strategy magnitude and direction of forces in structure members are managed and optimized through structural form. This approach results in structural configurations that are highly efficient in terms of strength-to-weight, and can offer great resistance to any foreseeable lateral loads from earthquakes or wind. The form of the Pearce Ecohouse is designed according to this principle, results in a structure of high strength and low material weight."

In Closing:

The above is a brief sketch of a bold proposal, but I believe that meeting Portland's immediate and long-term housing needs requires bold thinking and bold action. Considering that existing neighborhoods and commercial areas have utility and transportation infrastructure in place, and are near stores, services, schools, and parks, etc., we can all recognize the enormous social and economic value of infilling within the existing urban area. It is thus imperative to consider and act upon all reasonable infill strategies. I regard spaceframe as a very credible infilling tool. Peter Pearce's body of art in this field is a 'gift' that we can and should attend to. We can create a future of housing that is not just about brick boxes. I believe that undertaking a 'proof of concept' spaceframe project, in the immediate term, represents a tremendous opportunity for Portland to show world leadership in urban development innovation.

Regards,
Skip Trantow